

SHORT NOTES

Delayed metamorphosis of frog tadpoles at high altitude in Perthshire

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On the 26th September 1997 I was walking along the water-line of Lochan Uaine (Grid Ref. NO0479, 865 m a.s.l.) in Perthshire and witnessed a strange phenomenon. As I walked along small tailless recently metamorphosed froglets hastily hopped across the gravel shore to the cover of the nearby vegetation, at the same time in the edge of the water outsized tadpoles with partially developed hind legs were swimming swiftly towards the deeper water. Rather puzzled at the discrepancy in development of the two cohorts I captured a few of each to confirm that both were *Rana temporaria*, the common frog. I have come across odd ones of these enlarged tadpoles before in the hills, but had assumed them to be abnormal individuals with thyroid problems. For discussion of this phenomenon in lowland situations see Archibald and Downie (1996). However at Lochan Uaine there were approximately equal numbers of metamorphosed small froglets and enlarged tadpoles which suggested a natural phenomenon rather than an abnormality. In these enlarged tadpoles, the hindlimbs were present but not yet functional and the tail was still strongly developed. The lochan is quite small, 100m by 50m, but at the edges falls away rapidly to a depth in excess of 3m at the centre. Unfortunately it was not surveyed by Murray and Pullar (1910) so its precise depth is not known. The first 1.5m out into the lochan from the water's edge is devoid of vegetation, presumably due to ice action during winter, but the central area has a muddy bottom supporting abundant vegetation (hence the lochan's name; *Uaine* = green). Repeat visits to the lochan showed that these enlarged tadpoles (Fig. 1) persisted well into early winter. Preserved material from subsequent visits produced tadpole dimensions as shown in Table 1.

The latest tadpoles were collected on 31st November 2001 and were all either extracted from under the overhanging bank at the loch-edge or dredged from the mud amongst the vegetation in the deeper water. A similar phenomenon was observed by Gaddow in 1899 in North Wales but he implied that the tadpoles entering hibernation were rather small (see Smith, 1951). Similar enlarged tadpoles also occur in other upland lochans. In a small pool at 960m near the summit of Meall nan Tarmachan (Grid Ref.

NN582386) the phenomenon is more extreme in that it appears that none of the tadpoles metamorphose the year of hatching but all undergo delayed development and enlargement. Thus no froglets could be found in the water or nearby on any of the autumn visits. In contrast, another pool on the same hill (Grid Ref. NN579386) which is lower (910m) and heavily vegetated, contained only tadpoles that were actively metamorphosing on 11th September 2002 (Table 2 and Fig. 2).

Date	n	Body length	Body width	Tail length	Hindlimb length
08 Aug 2001	3	15.7	11.3	23.2	2.5
		14.5-	10.5-	22.0-	2.0-3.0
		16.5	12.0	25.5	
31 Nov 2001	2	16.3	11.0	27.3	9.3
		15.0-	10.5-	27.0-	9.0-9.5
		17.5	11.5	27.5	

Table 1. Average dimensions with ranges (mm) of tadpoles in Lochan Uaine (865m a.s.l.)

	Body length	Body width	Tail length	Hindlimb length
Pool at 910m	13.5	9.5	19.0	4.5
	13.0	9.0	19.5	5.0
	12.5	8.5	18.0	6.0
	12.5	8.5	19.5	8.0
	10.5	7.0	17.0	9.0
	10.5	5.5	15.0	9.0*
Pool at 960m	10.0	5.0	15.5	9.0*
	16.5	12.0	23.0	2.0
	15.5	11.5	23.0	3.5
	16.0	12.0	25.0	4.5
	17.5	12.5	27.5	7.5

Table 2. Dimensions (mm) of individual tadpoles in the two pools on Meall nan Tarmachan on 11.ix.2002. *Forelimbs also present

A later visit to the upper pool in early December yielded a single enlarged tadpole showing that survival in this stage is markedly prolonged. This visit on the 5th December 2002 was particularly significant as by this time the pool had frozen over and thawed several times and in fact was covered by 7cm of slush-ice at the time of the visit. Many enlarged tadpoles were lying dead on the peaty bottom of the pool. However, careful searching yielded a live individual that, at a depth of about 30cm, had burrowed several centimetres into the side of a peat-like vegetation matt that was close to the overflow-burn. The dead individuals, which appeared to have been dead for some time, were presumably those that failed to seek refuge early enough. This December tadpole (Fig. 3) was 14mm long by 10mm broad with a strong tail of 25.5mm. Its hindlimbs were well developed and some 11.5mm long. The forelimbs,

which were still internal, could be seen through the skin. The sternal muscles were developing and the head was starting to take on a more angular appearance but the tail was large and muscular, with well-developed myotomes.

Unfortunately no enlarged tadpoles or partially metamorphosed froglets have been found immediately post winter. However, it seems reasonable to assume that some make it through the winter as spawn appears each spring (*circa* 13th April) in the Tarmachan pool; this spawn is presumably produced by individuals that have originated in the pool in previous years. According to Smith (1951) frogs may return year after year to the same pond.



Fig. 1. Two tadpoles taken in Lochan Uaine on 8.viii.2001 (above) and 31.xi.2001 (below). The scale bar is 1cm long.

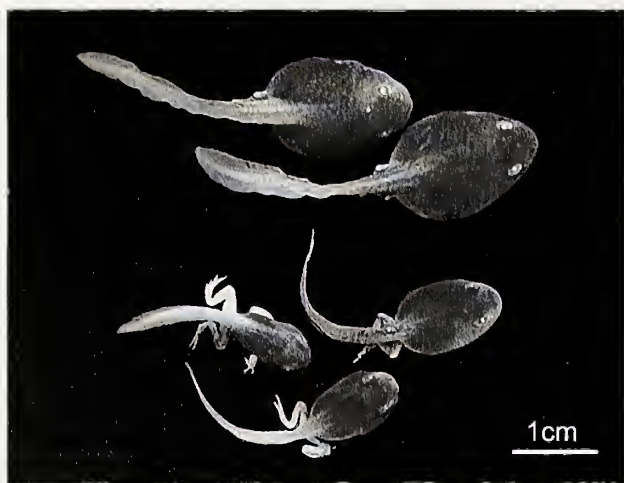


Fig 2. Two batches of tadpoles taken in lochans on Meall nan Tarmachan on 11.ix.2002. The three metamorphosing individuals near the 1cm scale bar are from 910m; the two larger individuals are from 960m.



Fig. 3. The tadpole found at 960m on Meall nan Tarmachan on 5.xii.2002. The scale bar is 1cm long.

In conclusion it is hypothesised that at altitudes over about 850m, metamorphosis at the usual size would produce very small frogs very late in the season. These would be compromised going into hibernation straight away. From the observations above it appears that upland frogs have a strategy for overcoming the short developmental period available at high altitude, namely: (a) Some or all individuals prolong their aquatic phase and become abnormally large. They slowly develop their hindlimbs while retaining a functional tail, thus retaining their ability to swim, (b) A genetic factor seems to be involved, hence the 50/50 split under identical conditions in the original observation at Lochan Uaine. It also appears to be influenced by altitude, hence all individuals metamorphosed normally in September at 910m, but all remained aquatic into winter at 960m on the same hill, (c) Metamorphosis of the enlarged tadpoles may proceed at a very much reduced rate during the winter sojourn below water. Currently the time of completion is unknown to me. (d) This delayed development probably only occurs in suitable water bodies where some protection from freezing is available such as a muddy bottom in deep water or porous peat bank abutting deep water. It has not been observed in any of the shallow upland lochans with a stony bottom that have been checked by me at the appropriate time.

More observations are obviously needed to establish the details of this alternative survival strategy. I am very grateful to Geoff Swinney of the National Museums of Scotland for useful discussions and confirmation of the identity of the *Rana temporaria* juveniles and tadpoles.

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